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MULTIMEDIA LEVELS

TRICHLOROETHYLENE

SEPTEMBER 1977

ENVIRONMENTAL PROTECTION AGENCY
OFFICE OF TOXIC SUBSTANCES
WASHINGTON, D.C. 20460

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16. ABSTRACT

This report discusses environmental levels of trichloroethylene (TCE) based on a review of the literature and other information sources. The concentration of TCE in the atmosphere of the U.S. ranges from about 1 ppt in remote areas to over 100 in areas near where the substances is manufactured or used. TCE concentrations in sediments range from less than 0.04 ppb to over 100 ppb. Again the high concentrations were found near manufacturing sites, but some of the lowest concentrations were as well. Soil concentrations appear to be no higher near manufacturing sites than in rural areas, though the data are very limited. The concentrations are a few ppb or less. Surface-water concentrations of TCE range from less than 1 ppb (the limit of detection) to several hundred ppb in the vicinity of a manufacturing site. Measured concentrations in U.S. drinking water are less than 1 ppb. The only degradation products of TCE that may exist in the environment in appreciable quantities for any period of time are dichloroacetyl chloride produced by the photodegradation of TCE in the atmosphere and dichloroacetic acid produced by the hydrolysis of dichloroacetyl chloride. There are very few data on the presence of TCE in food raised and sold in the U.S. However, data from the United Kingdom suggest that concentrations of TCE on the order of parts per billion are found in almost all common foodstuffs. There is little evidence to judge whether TCE is accumulating in living systems. Limited data on concentrations in human tissue and in marine organisms show levels on the order of a few parts per billion.

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EXECUTIVE SUMMARY

This report discusses environmental levels of trichloroethylene (TCE) based on a review of the literature and other information sources.

The concentration of trichloroethylene in the atmosphere of the U.S. ranges from about 0.005 $\mu g/m^3$ (1 ppt) in remote areas to over 500 $\mu g/m^3$ (100 ppb) in areas near where the substance is manufactured and used. The concentration drops off rapidly as one moves away from a source facility.

Trichloroethylene concentrations in sediments range from less than 0.04 ppb to over 100 ppb. Again the high concentrations were found near manufacturing sites, but some of the lowest concentrations were, as well.

Soil concentrations of trichloroethylene appear to be no higher near manufacturing sites than in rural areas, though the data are very limited. The concentrations are a few ppb or less.

Surface-water concentrations of trichloroethylene ranged from less than 1 ppb (the limit of detection) to several hundred ppb in the vicinity of a manufacturing site. One measurement as high as 5 ppm was made in a canal of stagnant water near a production site.

Measured concentrations of trichloroethylene in U.S. drinking water are less than 1 ppb, except in unusual circumstances such as in Des Moines, Iowa. Here, trichloroethylene contamination from an unidentified source resulted in levels as high as 80 ppb.

The only degradation products of trichloroethylene that may exist in the environment in appreciable quantities for any period of time are dichloroacetyl chloride produced by the photodegradation of trichloroethylene in the atmosphere and dichloroacetic acid produced by the hydrolysis of dichloroacetyl chloride. There is some evidence that the ultimate fate of dichloroacetyl chloride and dichloroacetic acid is degradation by microorganisms. Although the degradation products have not been determined, they are probably carbon dioxide and chloride ions.

There are very few data on the presence of trichloroethylene in food raised and sold in the U.S. However, data from the United Kingdom suggest that concentration of trichloroethylene on the order of parts per billion are found in almost all common foodstuffs.

There is little evidence to judge whether trichloroethylene is accumulating in living organisms. Limited data on trichloroethylene concentrations in human tissue and in marine organisms show levels on the order of a few parts per billion.

The data are also insufficient to enable trends in trichloroethylene levels in the environment to be determined.

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1. INTRODUCTION

Trichloroethylene (TCE) is one of the chemicals whose health and ecological effects, environmental behavior, and technologic and economic aspects are important to the U.S. Environmental Protection Agency. The literature has been searched in an effort to determine the environmental levels of trichloroethylene, the behavior of trichloroethylene in the environment, and the ways in which trichloroethylene may come in contact with man.

The literature has been examined using the following search strategy. An initial computer search of the following data bases was conducted.

- National Technical Information Service (NTIS)
- Smithsonian Science Information Exchange (SCD-SSIE)
- Engineering Index
- Pollution Abstracts
- TOXLINE
- MEDLARS (National Library of Medicine's National Interactive Retrieval Service)
- Air Pollution Technical Information Center (APTIC)
- USGS Water Quality Monitoring Data.

All searches were carried out in June, 1976. Original journal articles with relevant titles or abstracts were then examined and data extracted. In addition, various journals were screened manually through December, 1976. These journals included: Analytical Chemistry, Atmospheric Environment, Bulletin of Environmental Contamination and Toxicology, CRC Critical Reviews in Environmental Control, Environment, Environmental Pollution, Environmental Research, Environmental Science and Technology, International Journal of Environmental Analytical Chemistry, Journal of Environmental Science and Health, Journal Water Pollution Control Federation, and Water Research. Other journals were also screened but are not listed because they did not cover the indicated period, or were of more limited interest to those seeking information on environmental levels of trichloroethylene.

Several important reviews on the subject of trichloroethylene were also consulted. Specifically, a preliminary study of selected potential

environmental contaminants including trichloroethylene (U.S. Environmental Protection Agency, 1975a), a preliminary economic impact assessment of possible regulatory action to control atmospheric emissions of selected halocarbons (Shamel et al., 1975), an impact overview and an abstracted literature collection on trichloroethylene (Waters et al., 1976), an air pollution assessment of trichloroethylene (Fuller, 1976), a criteria for a recommended standard for occupational exposure to trichloroethylene (U.S. National Institute for Occupational Safety and Health, 1973), and a proposed occupational exposure standard for trichloroethylene (U.S. Department of Labor, 1975) were consulted.

2. OCCURRENCE OF TRICHLOROETHYLENE IN THE ENVIRONMENT

TRICHLOROETHYLENE IN THE ATMOSPHERE

No extensive monitoring program designed specifically for trichloroethylene have been identified. However, trichloroethylene has been detected along with other halocarbons at various locations throughout the U.S. and around the world. The most extensive data are reproduced in Tables 2.1 and 2.2. These data are taken from a study done at Cook College, Rutgers University (lillian et al., 1975). Other data are summarized in Table 2.3.

A program to determine environmental levels of trichloroethylene was initiated in 1976 at Battelle's Columbus Laboratories. During late 1976 and early 1977, samples were collected from various production sites, a user site, and a background site. The samples were analyzed and the results are summarized in Tables 2.4 through 2.9 and in the corresponding maps of the plant locations on which the sampling sites are indicated (Figures 2.1 through 2.6). Details of the results and methodology are given in a companion report, EPA-560/6-77-024 (Battelle's Columbus Laboratories, 1977).

The concentration of trichloroethylene in the atmosphere ranges from about 0.005 $\mu g/m^3$ (1 ppt) in remote areas to over 500 $\mu g/m^3$ (100 ppb) in areas where the substance is manufactured or used. As one moves away from a manufacturing facility, the concentration of trichloroethylene in air drops off rapidly.

As shown in Tables 2.4, 2.5, and 2.6, the highest concentrations of trichloroethylene are generally observed downwind from a producer or user site and the concentration seems to be dependent on the distance from the discharge point. Most of the higher concentrations are observed at distances of less than 1 km. Considerable variation, however, was observed in the maximum downwind levels of trichloroethylene at various production sites. The variations in the observed maximum concentrations among plants may be due to differences in (1) production processes, (2) emission control equipment, (3) meteorological conditions, and (4) distance from the plant. Higher production capacity apparently does not necessarily imply higher emissions since the maximum concentrations observed at the larger plants were no higher than those observed at the smaller operations, and were sometimes lower. Large temporal variations are observed when measuring these chlorinated hydrocarbons downwind from a production facility. Changes in meteorological conditions, particularly wind speed and direction, and/or variations in the emissions may account for this phenomenon.

TABLE 2.1. MAXIMUM AND MINIMUM LEVELS OF TRICHLOROETHYLENE IN THE ATMOSPHERE AT VARIOUS LOCATIONS IN THE UNITED STATES

Monitoring Period and Location	Levels	Concentration, ppb
June 18-19, 1974	Max.	2.8
Seagirt, New Jersey	Min.	<0.05
(National Guard Base)	Mean	0.26
June 27-28, 1974	Max.	1.1
New York, New York	Min.	0.11
(45th & Lexington)	Mean	0.71
July 2-5, 1974	Max.	0.80
Sandy Hook, New Jersey	Min.	<0.05
(Fort Hancock)	Mean	0.34
July 8-10, 1974	Max.	0.56
Delaware City, Delaware	Min.	<0.05
(Road 448 & Route 72 intersection)	Mean	0.35
July 11-12, 1974	Max.	<0.05
Baltimore, Maryland	Min.	<0.05
(1701 Poncabird Pass, Ford Holabird area)	Mean	----
July 16-26, 1974	Max.	0.63
Wilmington, Delaware	Min.	<0.05
(Clinton County Air Force Base)	Mean	0.19
September 16-19, 1974	Max.	0.35
White Face Mountains	Min.	<0.05
(New York State)	Mean	0.10
March-December, 1973	Max.	8.8
Bayonne, New Jersey	Min.	<0.05
	Mean	0.92

Source: Lillian et al., 1975.

TABLE 2.2. TYPICAL LEVELS OF TRICHLOROETHYLENE IN THE ATMOSPHERE

Date and Time	Location	Concentration, ppb
June 27, 1974 2300	New York, New York	0.11
September 17, 1974 1200	White Face Mountains New York State (nonurban)	<0.02
July 2, 1974 1400	Over Ocean Sandy Hook, New Jersey 4.8 km (3 mi.) offshore	0.18
July 19, 1974 1300	Seagirt, New Jersey (National Guard Base)	<0.02
July 17, 1974 1228	Above the Inversion elevation 1500 m (5000 ft) Wilmington, Ohio	<0.02
July 17, 1974 1203	Inversion Layer elevation 450 m (1500 ft) Wilmington, Ohio	0.075

Source: Lillian et al., 1975.

TABLE 2.3. MISCELLANEOUS MONITORING DATA FOR TRICHLOROETHYLENE IN THE ATMOSPHERE

Location	Date of Data Collection	Concentration	Method[a]	Reference
New Brunswick NJ	1973	Detected	Coulometric GC	Lillian and Singh, 1974
" "	Unreported	0.75 ppb	" "	" "
Kansas City-NASN Station	1974	Detected	GC/MS	Bunn et al., 1975
Houston TX and vicinity	Nov. 1974	"	GC/MS computer	Pellizzari et al., 1976
Los Angeles Basin	April 1975	"	" "	" "
Worldwide	1974	5 ppb	Estimate	Goldberg, 1975
Pullman WA	Dec. 1974 to Feb. 1975	<5 ppt	GC/MS	Grimsrud and Rasmussen, 1975
Western Ireland	June/July 1974	15 ppt	Coulometric GC	Lovelock, 1974
North Atlantic	Oct. 1973	<5 ppt	" "	" "
Northern Hemisphere	1974	15 ppt	EC/GC	Cox et al., 1976
Southern Hemisphere	1974	1.5 ppt	"	" "
Liverpool, England	March 1972	850 ng/m^3 (~160 ppt)	"	Murray and Riley, 1973
Rural areas of Britain	1972	11 ng/m^3 (average)	"	" "
Over the northeast Atlantic	Aug. 1972	6 ng/m^3	"	" "
Britain, perimeter of a manufacturing plant	1972-1974	40-64 ppb (mass)	"	Pearson and McConnell, 1975
Heath, near the above plant	"	12-42 ppb (mass)	"	" "
Suburban area, removed from plant	"	1-20 ppb (mass)	"	" "
Tokyo	May 1974-April 1975	1.2 ppb (annual average)	"	Ohta et al., 1976

TABLE 2.4. CONCENTRATION OF TRICHLOROETHYLENE IN AIR, WATER, SOIL, AND SEDIMENT AT DOW CHEMICAL PLANT B (TRICHLOROETHYLENE PRODUCER)

Air			
Site	Concentration, ppbv[a]	Distance from Plant, km	Upwind (U), Downwind (D), or Variable (V)
1B	<1	1.9	-
2B	<1	1.4	U
3B	<1	1.8	-
4B	<1	2.4	D
5B	<1 to 11.5	2.4	D
6B	<1	3.4	D
7B	<1	3.1	D
8B	<1 to 4.4	4.4	D
9B	<1	3.5	D

Water, Soil, and Sediment		
Site	Description of Media	Concentration, ppb
A3	Surface water, mouth of plant effluent canal	172
A4	Water, as above except 4 m deep	197
A5	Surface water, 400 m downstream from plant outfall	5
A6	Water, as above except 5 to 6 m deep	13
A7	Surface water, 800 m upstream of plant outfall	0.9
A9, A10, A11, A13	Soil, approximately 2 km from plant	<0.06 to 0.45
A3S	Sediment, mouth of plant effluent canal	0.15
A5S	Sediment, 400 m downstream of plant outfall	None detected
A7S	Sediment, 800 m upstream of plant outfall	0.04

[a]Limits of detection: 1 ppbv. To convert to $\mu g/m^3$ at 25 C, multiply ppbv by 5.37.

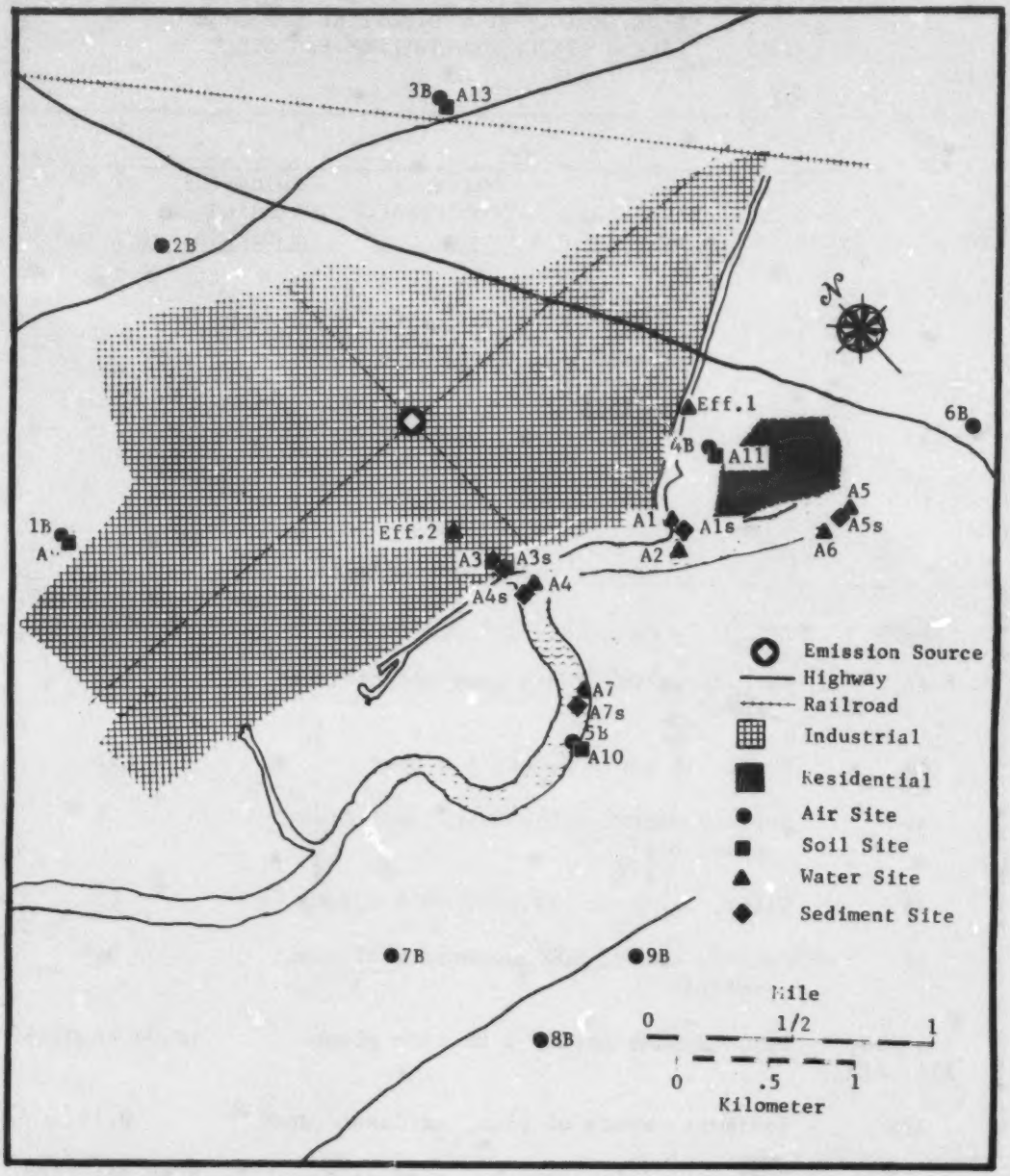


Figure 2.1. Sampling locations at Dow Chemical Plant B, Freeport, Texas--trichloroethylene production site.

TABLE 2.5. CONCENTRATION OF TRICHLOROETHYLENE IN AIR, WATER, SOIL, AND SEDIMENT AT HOOKER CHEMICAL COMPANY (TRICHLOROETHYLENE PRODUCER)

Air

Site	Concentration, ppbv[a]	Distance from Plant, km	Upwind (U), Downwind (D), or Variable (V)
1	21 to 140	0.2	D
2	<1	0.6	U
3	<1 to 5.4	0.8	U
4	<1 to 270	0.5	V
5	<1	2.7	-
6	<1	2.2	-
7	<1	1.1	D
8	<1 to 6.0	1.8	D
9	<1 to 45	1.8	D

Water, Soil, and Sediment

Site	Description of Media	Concentration, ppb
B1	Surface water, Mississippi River, 150 m upstream of plant outfall	1
B2	Surface water, at plant outfall	535
B3	Surface water, 1 km downstream of plant outfall	22
B10	Surface water, open stagnant canal about 2.7 km from plant	5,227
B5, B6, B7, B8	Soil, close to the plant out to about 2.7 km	0.23 to 5.6
B1S	Sediment, 150 m upstream of plant outfall	0.18
B2S	Sediment, 100 m downstream of plant outfall	0.63
B3S	Sediment, 200 m downstream of plant outfall	0.03

[a]Limits of detection: 1 ppbv. To convert to $\mu g/m^3$ at 25 C, multiply ppbv by 5.37.

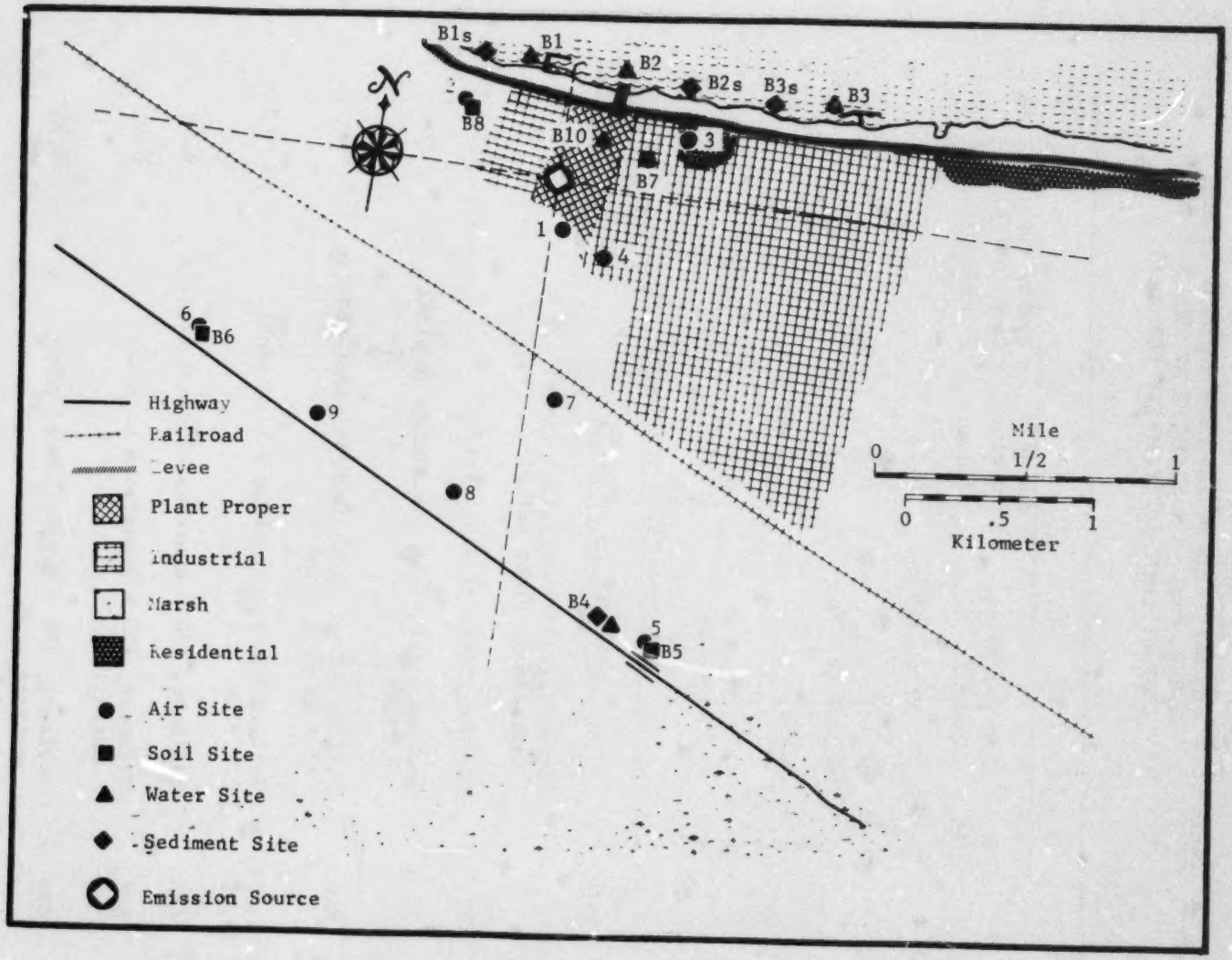


Figure 2.2. Sampling locations at Hooker Chemical, Hahnville, Louisiana--trichloroethylene production site.

TABLE 2.6. CONCENTRATION OF TRICHLOROETHYLENE IN AIR, WATER, SOIL, AND SEDIMENT AT ETHYL CORPORATION (TRICHLOROETHYLENE PRODUCER)

Air

Site	Concentration, ppbv[a]	Distance from Plant, km	Upwind (U), Downwind (D), or Variable (V)
1	1.9 to 5.6	0.4	D
2	<1 to 7.2	0.2	D
3	<1	2.4	D
4	<1	2.6	D
5	<1	2.2	-
6	<1	0.7	U
7	<1	2.2	-
8	<1	3.2	D

Water, Soil, and Sediment

Site	Description of Media	Concentration, ppb
C1	Surface water immediately above settling pond	128
C2	Surface water, 200 m upstream of plant outfall	0.4
C3	Surface water, 300 m downstream of plant outfall	37
C4 to C7	Soil, various locations in vicinity of plant	None detected
C2S	Sediment, 200 m upstream of plant outfall	None detected
C3S	Sediment, 300 m downstream of plant outfall	116

[a]Limits of detection: 1 ppbv. To convert to $\mu g/m^3$ at 25 C, multiply ppbv by 5.37.

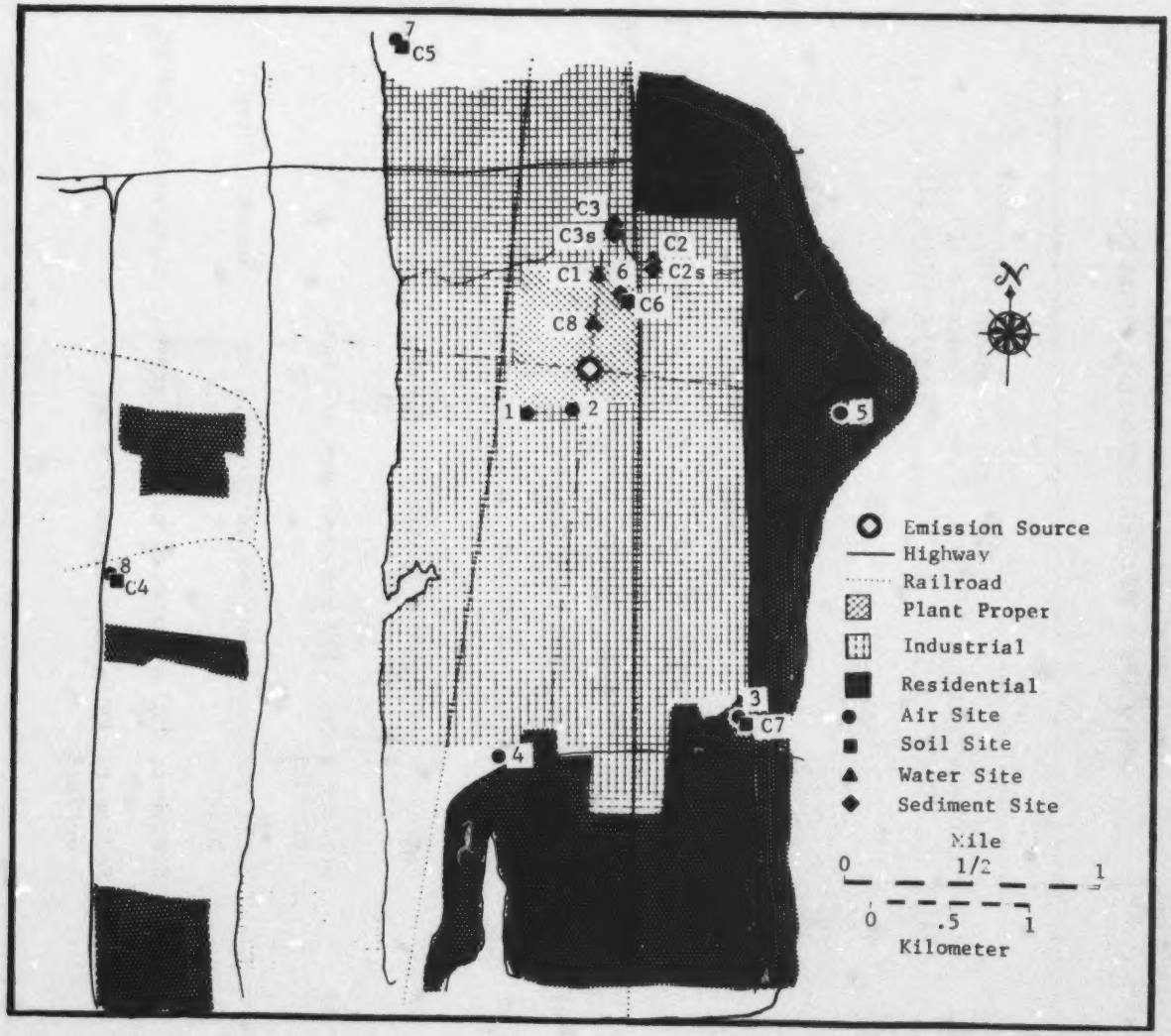


Figure 2.3. Sampling locations at Ethyl Corporation, Baton Rouge, Louisiana--trichloroethylene production site.

TABLE 2.7. CONCENTRATION OF TRICHLOROETHYLENE IN AIR, WATER, SOIL, AND SEDIMENT AT PPG INDUSTRIES (TRICHLOROETHYLENE PRODUCER)

Air			
Site	Concentration, ppbv[a]	Distance from Plant, km	Upwind (U), Downwind (D), or Variable (V)
1	2.2 to 2.7	1.3	U
2	<1	4.2	U
3	<1	3.5	V
4	<1	2.7	U
5	<1	1.4	D
6	<1 to 12	4.0	D
7	<1	0.6	U
8	<1	1.3	-

Water, Soil, and Sediment		
Site	Description of Media	Concentration, ppb
F1	Surface water, 50 m upstream of plant outfall	353
F2	Surface water, at plant outfall No. 1	447
F3	Surface water, at plant outfall No. 2	179
F4	Surface water, 50 m downstream of outfall No. 2	403
F5	Surface water, lake--downstream of plant outfalls	29
F6 to F9	Soil, quadrants surrounding plant	None detected to 0.11
F1S	Sediment, 50 m upstream of plant outfall	146
F3S	Sediment, at plant outfall No. 2	15

[a]Limits of detection: 1 ppbv. To convert to $\mu g/m^3$ at 25 C, multiply ppbv by 5.37.

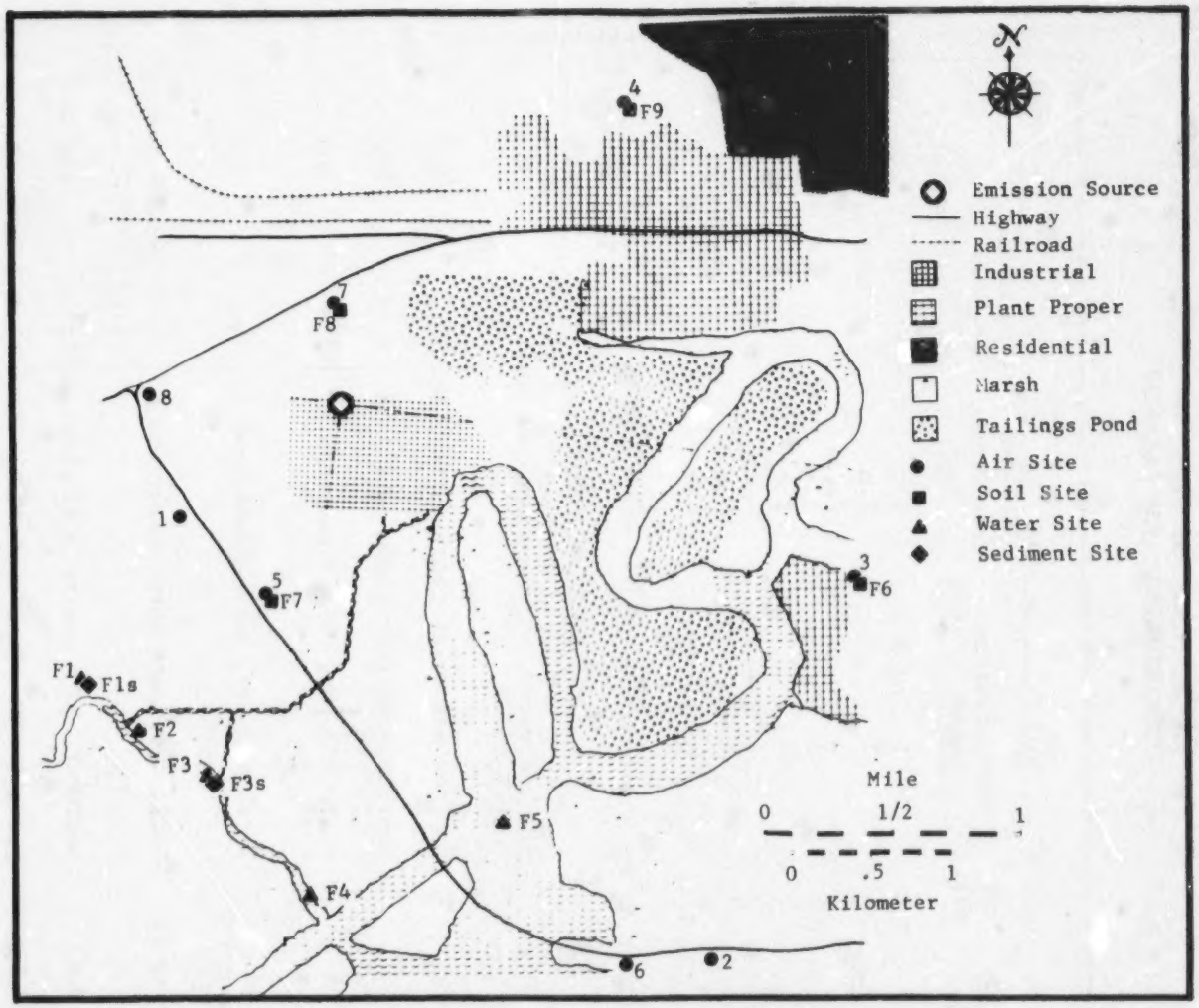


Figure 2.4. Sampling locations at PPG Industries, Lake Charles, Louisiana--trichloroethylene production site.

TABLE 2.8. CONCENTRATION OF TRICHLOROETHYLENE IN AIR AT BOEING COMPANY (TRICHLOROETHYLENE USER)

Site[a]	Concentration, ppbv[b]	Distance from Plant, km
1	<1	0.6
2	<1	1.1
3	17 to 38	0.4
4	15 to 44	0.5

[a]All sites were downwind at time of measurements.

[b]Limit of detection, 1 ppbv. To convert to $\mu g/m^3$ at 25 C, multiply ppbv by 5.37.

TABLE 2.9. CONCENTRATION OF TRICHLOROETHYLENE IN AIR, WATER, SOIL, AND SEDIMENT AT ST. FRANCIS NATIONAL FOREST (BACKGROUND)

Media	Concentration
Air	<1.0 ppbv
Surface water, from lake	0.05 ppb
Soil	0.63 ppb
Sediment	2.2 ppb

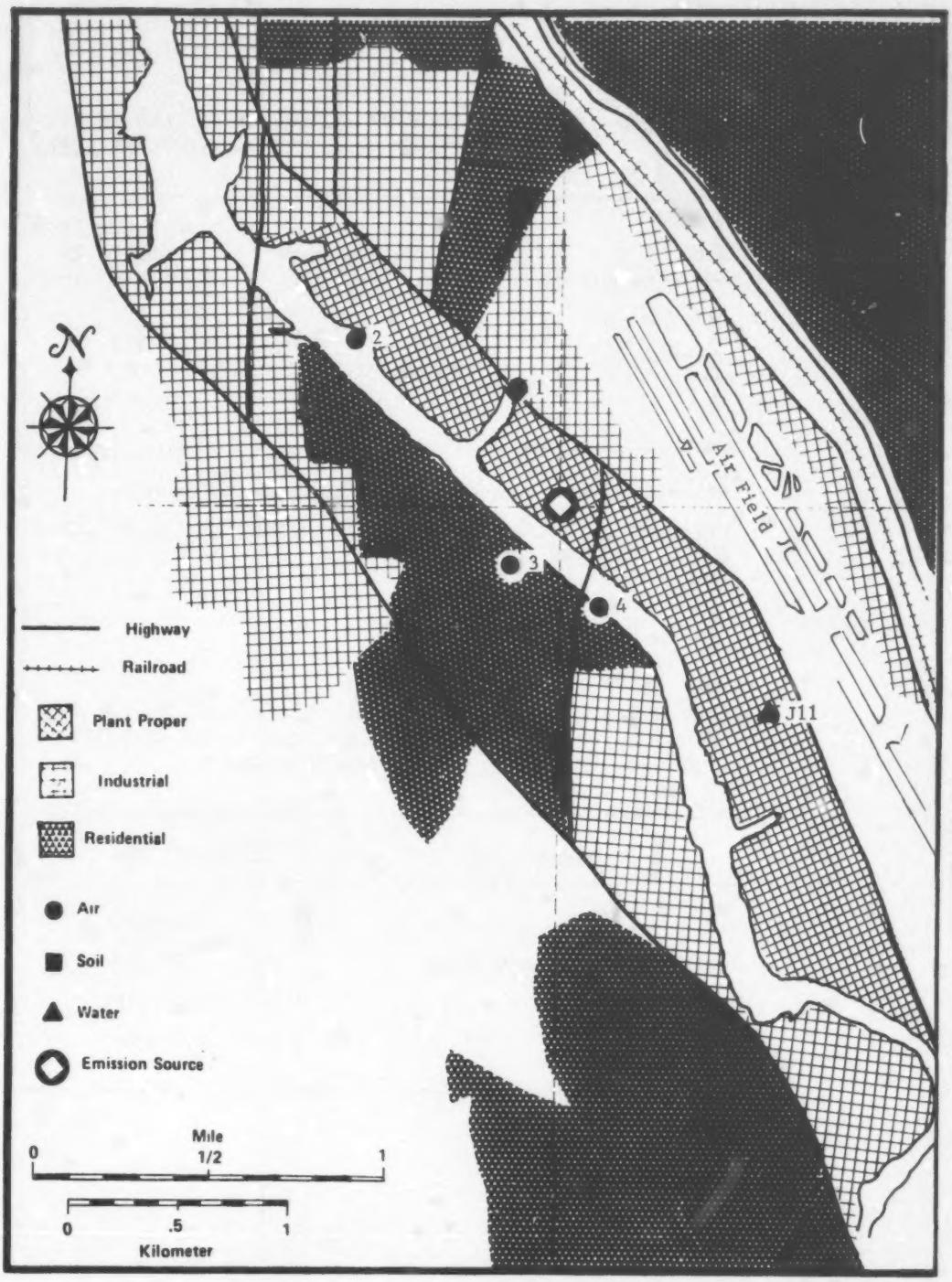


Figure 2.5. Sampling locations at Boeing Company, Seattle, Washington--trichloroethylene user site.

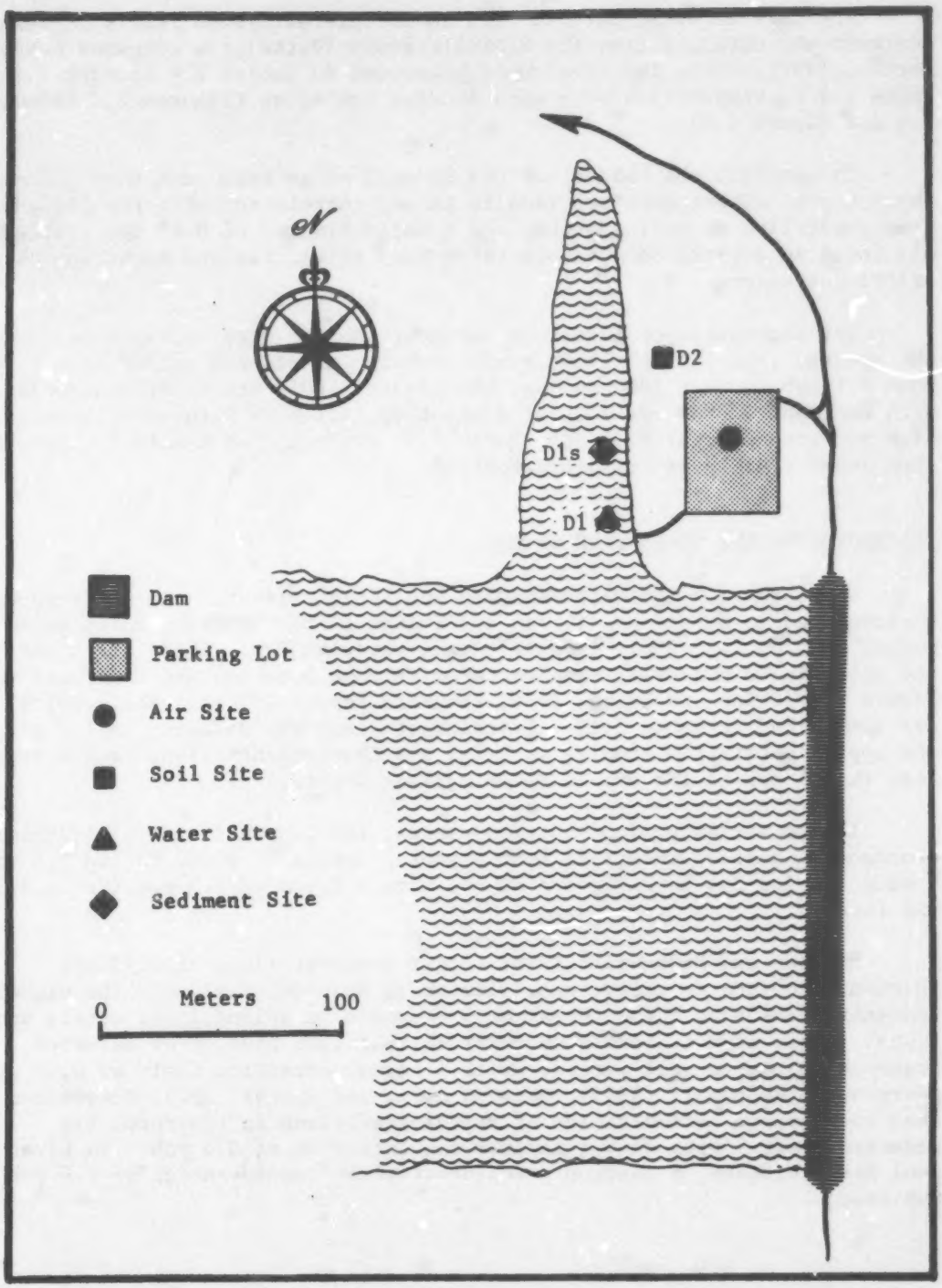


Figure 2.6. Sampling locations at St. Francis National Forest, Helena, Arkansas--background site.

TRICHLOROETHYLENE IN SOIL AND SEDIMENT

The only information available on trichloroethylene levels in soil and sediment was obtained from the Battelle study (Battelle's Columbus Laboratories, 1977). This information is presented in Tables 2.4 through 2.7 and Table 2.9 in conjunction with maps showing the sites (Figures 2.1 through 2.4 and Figure 2.6).

In general, the concentrations in soil range from less than 0.1 ppb to about 6 ppb. There does not seem to be any correlation with the distance from production or user sources, and a concentration of 0.63 ppb (Table 2.9) was found in a background sample taken many miles from any known source of trichloroethylene.

Trichloroethylene levels in sediment samples were somewhat higher on the average than the levels in soil. Levels in sediment ranged from less than 0.1 ppb to over 100 ppb, but the higher levels are usually associated with sediment in the vicinity of a plant outfall. As with soil, a relatively high background level (2.2 ppb, Table 2.9) was found at a site far removed from known sources of trichloroethylene.

TRICHLOROETHYLENE IN SURFACE WATERS

Approximately 200 water samples have been collected and analyzed for various organic substances (Chian and Ewing, 1976). These samples were collected from 14 heavily industrialized river basins. These areas and the approximate number of samples taken at each location are indicated in Figure 2.7 (Chian and Ewing, 1976, Progress Report No. 4). The results are summarized in Table 2.10. Trichloroethylene was detected in 142 of the approximately 200 samples analyzed and the concentrations ranged from less than 1 ppb to 188 ppb in these surface waters.

In the vicinity of production plants, the concentration of trichloroethylene in surface waters is much higher. Levels from 200 to 400 ppb are common (Tables 2.4 to 2.7), and at one site a level of 5.2 ppm (Table 2.5) was found.

Pearson and McConnell (1975) report concentrations of 0.15 ppb trichloroethylene in rainwater collected in Runcorn, England. The highest concentrations that these researchers measured in upland river waters was 6 ppb. These same authors also reported that they have never detected organochlorines in well waters. With a normal detection limit of 0.01 ppb, Pearson and McConnell (1975), between April and August, 1973, determined that the average concentration of trichloroethylene in Liverpool Bay seawater was 0.3 ppb, with a maximum concentration of 3.6 ppb. In Liverpool Bay sediments, a maximum trichloroethylene concentration of 9.9 ppb was found.

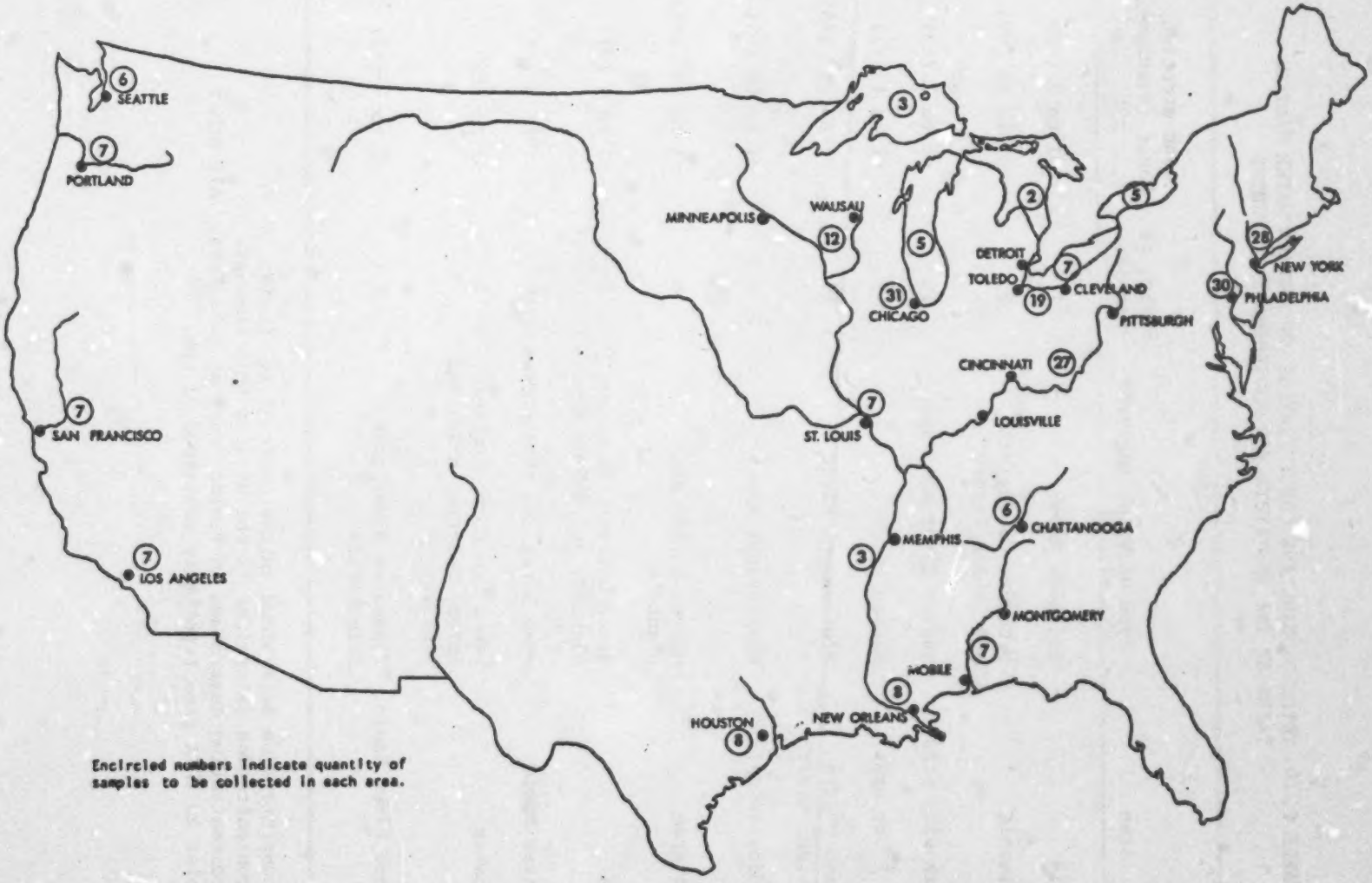


Figure 2.7. Industrialized area where surface water was sampled (Source: Chian and Ewing, 1976).

TABLE 2.10. TRICHLOROETHYLENE CONCENTRATION IN SURFACE WATER SAMPLES TAKEN BY THE INSTITUTE FOR ENVIRONMENTAL STUDIES

Area	Type of Water Analyzed	Number of Samples	Concentration Range (Average), ppb
Illinois	Illinois River	11	<1 to 7 (<2)
Pennsylvania	Delaware, Schuylkill, and Lehigh Rivers	25	<1 to 18 (<2)
New York City area	Hudson River and bays	16	<1 to 7 (<3)
Hudson River area	Hudson River	12	<1 to 4 (<1)
Upper and Middle Mississippi River	Mississippi River	19	<1 to 29[a] (<4)
Lower Mississippi River	Mississippi River	9	<1 to 20 (<5)
Houston area	Galveston Bay and channels	8	<1 to 29[b] (<5)
Alabama	Black Warrier, Tombigee, Alabama, and Mobile Rivers	7	<1 to 1 (<1)
Ohio River Basin	Ohio River and tributaries	10	<1 to 5 (<1)
Great Lakes	Lakes Superior, Michigan, Huron, Ontario, Erie, and vicinity	13	<1 to 188[c]
Tennessee River Basin	Tennessee River and tributaries	1	<1 to 3 (<2)

[a]This concentration determined on the shore at St. Louis.
[b]This concentration determined in the Houston Ship Channel.
[c]This concentration determined in Fields Brook at Lake Erie. All other samples in this area reportedly contained <1 ppb.

TRICHLOROETHYLENE IN DRINKING WATER

Shortly after the identification of trichloroethylene and other halogenated hydrocarbons in New Orleans drinking water, the results were published (Dowty et al., 1975a and 1975b), and several other significant events occurred. The Safe Drinking Water Act was signed into law in December, 1974, and a National Organics Reconnaissance Survey (NORS) was undertaken.

As part of the NORS, drinking water supplies at five selected sites were analyzed. These supplies were chosen to represent the major types of raw water sources in the United States at that time. The results for trichloroethylene are summarized in Table 2.11. The NORS was extended to cover a total of ten cities in the United States. In the extended survey, trichloroethylene was also detected, but not quantified, in the drinking water at Lawrence, Massachusetts (U.S. Environmental Protection Agency, 1975b). A follow-up study on finished and raw water samples from Miami, Florida, was carried out. The results of this study are summarized in Table 2.12.

TABLE 2.12. SOME OF THE ORGANIC COMPOUNDS IDENTIFIED IN MIAMI, FLORIDA, FINISHED AND RAW WATER SAMPLES (P = Present but not quantified; ND = Not detected)

Organic Compound Identified	Finished Water 1/29/75, ppb	Finished Water 7/7/75, ppb	Raw Water, 7/7/75, ppb	Test Well, 7/7/75, ppb
Trichloroethylene	P	P	P	ND
Methylchloroform	P	P	P	ND
Carbon tetrachloride	P	P	ND	ND
Chloroform	311	220	0.7	ND

Source: Keith, 1976.

Several U.S. Environmental Protection Agency regional offices have analyzed various waters for trichloroethylene. The Surveillance and Analysis Division of Region IV under the direction of James H. Finger has detected trichloroethylene at the following locations at the estimated concentrations shown:

Dalton, Georgia, Wastewater Treatment Plant <5 ppb
Rome, Georgia, Treatment Plant <0.5 ppb
Rome, Georgia, Wastewater Treatment Plant <5 ppb

TABLE 2.11. PROPERTIES AND TRICHLOROETHYLENE CONCENTRATION OF FINISHED WATER IN FIVE CITIES

City	Type of Supply	Type of Raw Water	Nonvolatile Total Organic Carbon, mg/ℓ	Conductivity, mmhos/cm	Chlorine, mg/ℓ	PH	Concentration, ppb
Cincinnati OH	Surface	Industrial waste	1.3	295	2.7	8.6	0.1
Miami FL	Ground	Natural waste	6.5	350	2.3	8.7	0.3
Ottumwa IA	Surface	Agricultural waste	2.3	500	1.4	9.2	<0.1
Philadelphia PA	Surface	Municipal waste	1.9	260	2.0	8.3	0.5
Seattle WA	Surface	Natural waste	1.0	50	0	6.6	Not detected

Source: Keith, 1976.

Region IV personnel also analyzed discharge from the Stauffer Chemical Company plant at Louisville and determined the trichloroethylene concentration to be 500 ppb. It is believed that Stauffer produces trichloroethylene at this plant. Region IV personnel may have conducted an organics study of the Ohio River, but this information is not yet available.

As a result of a National Organic Monitoring Survey conducted between March 1 and April 3, 1976, it was determined that trichloroethylene was present in the finished drinking water at Des Moines, Iowa, to the extent of 32 ppb. Through a series of analyses, it was determined that contamination of the gallery infiltration system was responsible for the presence of trichloroethylene in Des Moines drinking water. It was calculated that the levels of trichloroethylene in the Des Moines drinking water would result from the dumping of 1 gallon per day of this substance into the water system. The exact source was never located.

In an earlier, unrelated study (1974), raw wastewater processed in the Oro Loma Sanitary District of the San Francisco Bay area was estimated to contain 1.2 mg/ℓ in the 49,205 m^3/day average discharge (Camisa, 1975).

In an investigation of the chlorination of water for purification and the potential for the formation of potentially harmful chlorinated compounds by this process, Bellar et al. (1974) at the National Environmental Research Center of the Environmental Protection Agency at Cincinnati, Ohio, reported the following concentrations of trichloroethylene in water from a sewage-treatment plant: influent before treatment, 40.4 µg/ℓ; effluent before chlorination, 8.6 µg/ℓ; and effluent after chlorination, 9.8 µg/ℓ.

3. TRANSFORMATIONS OF TRICHLOROETHYLENE IN THE ENVIRONMENT

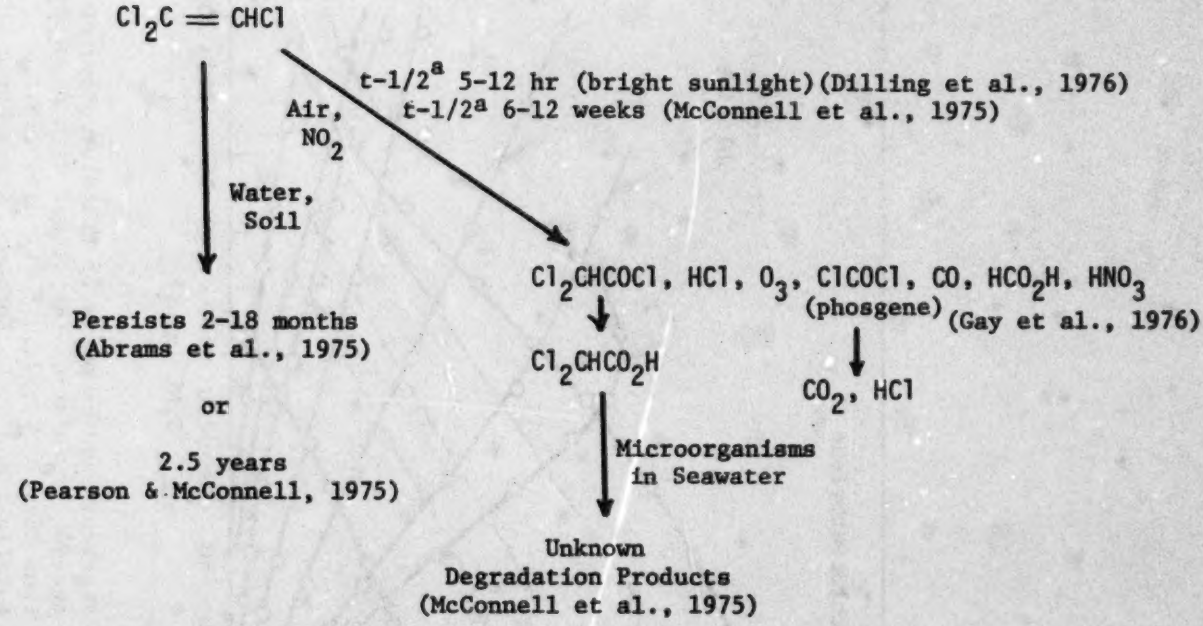
This section indicates the changes that trichloroethylene can undergo in various real and simulated environmental media. The information on the subject is summarized in Table 3.1 and represented graphically in Figure 3.1.

It appears that the only degradation products that may exist in the environment in appreciable quantities for any period of time are dichloroacetyl chloride produced by the photodegradation of trichloroethylene in the atmosphere and dichloroacetic acid produced by the hydrolysis of dichloroacetyl chloride. There is some evidence that the ultimate fate of the dichloroacetyl chloride and dichloroacetic acid is degradation by microorganisms (McConnell et al., 1975). Although the degradation products have not been determined, they are probably carbon dioxide and chloride ions which are already present in the environment.

The results of a detailed study showing the degradation of trichloroethylene in a photochemical chamber in the presence of nitrogen dioxide in air are shown in Figure 3.2 (Gay et al., 1976). The chamber was irradiated with ultraviolet light as the reactants and products were continuously monitored using long-path infrared spectroscopy. This study was undertaken in order to obtain more information on the atmospheric degradation of halogenated compounds, particularly with regard to the rates of photooxidation and the identity of photooxidation intermediates and final products.

TABLE 3.1. TRANSFORMATIONS OF TRICHLOROETHYLENE IN THE ENVIRONMENT

Media	Change or Products Observed	Reference
Photochemical Chamber, TCE (3.45 ppm) with NO_2 (2.66 ppm)	Dichloroacetyl chloride, HCl, CO, phosgene (TCE half-life: ∿2 hr)	Gay et al., 1976
Atmosphere near welding	HCl, Cl_2, and phosgene (severe decomposition, dangerous levels)	Rinzema and Silverstein, 1972
Smog chamber	Ozone	Farber, 1973
Atmosphere, xenon arc exposure	Dichloroacetic acid, CO_2, HCl	McConnell et al., 1975
Troposphere, 3.1 ppt	Disappearance with a half-life of 6 weeks (±50%)	Pearson and McConnell, 1975
Simulated atmosphere conditions--bright sunlight	Disappearance with a half-life of 5-12 hr	Dilling et al., 1976
Water containing natural and added contaminants--TCE at 1 ppm	Evaporation with a half-life of 19 min	Dilling et al., 1976



[a]t-1/2 = Time required for one-half of the chlorinated hydrocarbon to disappear by the indicated process.

Figure 3.1. Transformations of trichloroethylene.

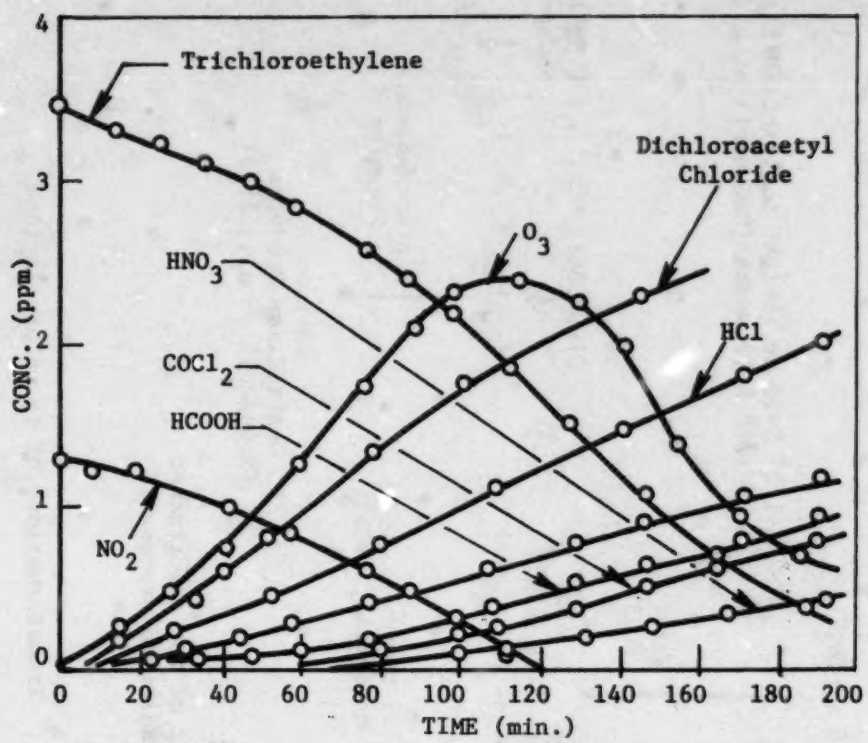


Figure 3.2. Reactants and products of trichloroethylene and NO_2 irradiation (Reprinted with permission from Gay, B. W., Jr., P. L. Hanst, J. J. Bufalini, and R. C. Noonan. Atmospheric Oxidation of Chlorinated Ethylenes. Environmental Science and Technology 10(1):65. Copyright by the American Chemical Society.)

4. OCCURRENCE OF TRICHLOROETHYLENE IN FOOD

There are very few data on the presence of trichloroethylene in food raised and sold in the United States, but there is some information on the presence of trichloroethylene in foodstuffs found in the United Kingdom. This information is summarized in Table 4.1. Trichloroethylene concentrations on the order of parts per billion are found in almost all common foodstuffs.

Trichloroethylene has also been used to extract spice oleoresins and to decaffeinate coffee. The FDA regulations of the concentration of trichloroethylene in these materials are listed in the section on Exposure and Biological Accumulation of Trichloroethylene in Man. In 1974, approximately 90 percent of the decaffeinated coffee was produced using trichloroethylene (Valle-Riestra, 1974); but since July, 1975, trichloroethylene has not been used by U.S. makers of decaffeinated coffee. It has largely been replaced by methylene chloride, according to FDA, even though the safety of methylene chloride has not been established. In a recent study, trichloroethylene was not detected in any of the oleoresins analyzed for that substance (Page and Kennedy, 1975).

TABLE 4.1. TRICHLOROETHYLENE IN FOODSTUFFS

Foodstuff	Concentration, µg/kg
Dairy products	
Fresh milk	0.3
Cheshire cheese	3
English butter	10
Hens eggs	0.6
Meat	
English beef (steak)	16
English beef (fat)	12
Pig's liver	22
Oils and fats	
Margarine	6
Olive oil (Spanish)	9
Cod liver oil	19
Vegetable cooking oil	7
Castor oil	Not detected
Beverages	
Canned fruit drink	5
Light ale	0.7
Canned orange juice	Not detected
Instant coffee	4
Tea (packet)	60
Wine (Yugoslav)	0.02
Fruits and vegetables	
Potatoes (S. Wales)	Not detected
Potatoes (N.W. England)	3
Apples	5
Pears	4
Tomatoes[a]	1.7
Black grapes (imported)	2.9
Fresh bread	7

Source: McConnell et al., 1975.

[a]Tomato plants were grown on a reclaimed lagoon at Runcorn Works of ICI.

5. EXPOSURE AND BIOLOGICAL ACCUMULATION OF TRICHLOROETHYLENE IN MAN

EXPOSURE

Estimates of the number of workers exposed to trichloroethylene by industry are given in Table 5.1. The table also indicates the diverse industries using this solvent. It is also estimated that approximately 5,000 medical, dental, and hospital personnel are routinely exposed to trichloroethylene as an anesthetic (Lloyd et al., 1975).

A 2-year series of studies involving cleaning operations throughout the United States was carried out by Dow Chemical (Skory, 1974). The purpose was to determine the extent of worker exposure during solvent vapor degreasing and to compare the three most commonly used chlorinated solvents: trichloroethylene, methylchloroform, and perchloroethylene. Dow estimates that there are over 25,000 chlorinated solvent vapor degreasers throughout the United States. The studies were conducted in the worker breathing zones which were adjacent to some 275 industrial vapor degreasing operations. The results of this study show that trichloroethylene and perchloroethylene vapor concentrations measured around vapor degreasers frequently exceeded the allowable standards for health and safety. Peak concentrations were high enough to present a definite health and safety hazard from anesthetic effects such as dizziness, lack of coordination, and impaired judgment. Although the national primary and secondary photochemical oxidant standards for chlorinated solvents are less than 3 lb/hr or 15 lb/day maximum for each piece of equipment, it is not uncommon for an idling, open-top (measuring 24 x 58 inches) vapor degreaser to lose 47 lb/day of trichloroethylene or 33/lb/day of methylchloroform (Archer, 1973). Judging from production figures, this material is being lost to the atmosphere and is then replaced.

It is estimated that 2×10^5 tons of chlorinated hydrocarbons are lost to the environment each year (Murray and Riley, 1973) and that 1×10^4 tons of trichloroethylene are discharged annually (Abrams et al., 1975).

It is estimated that 500 tons/day of industrial effluents are released into the air over Los Angeles County. Of this amount, 25 tons are dry cleaning fluids and 95 tons are degreasing solvents, that is, chlorinated hydrocarbons (Simmonds et al., 1974). Because trichloroethylene has been implicated as an oxidant-producing contaminant, its use in Los Angeles County has been restricted since 1967 (Farber, 1973). This restriction, the famous Rule 66, may provide a control in monitoring trichloroethylene. Since the amount of trichloroethylene over Los Angeles County should be reduced in relationship to other chloridnated hydrocarbons that have replaced it, the determination of the relative amounts there and over other cities where there are no restrictions should be very informative.

TABLE 5.1. OCCUPATIONAL EXPOSURE

Industry	Estimated Number Exposed
Agricultural services	124
Oil and gas extraction	267
Ordnance	57
Food products	2,502
Textile mill products	1,014
Apparel/textile products	858
Lumber products	72
Furniture manufacturing	162
Paper products manufacturing	2,240
Printing trades	2,876
Chemical manufacturing	9,552
Petroleum products	713
Rubber/plastics manufacturing	4,985
Leather products	725
Stone/clay products	2,685
Primary steel manufacturing	11,672
Metal fabrication	11,709
Machinery manufacturing	7,481
Electrical equipment	66,727
Transportation equipment	54,174
Instrument manufacturing	4,815
Miscellaneous manufacturing	1,516
Trucking/warehousing	642
Air transportation	23
Communication	5,560
Wholesale trade	3,327
Automotive dealer	223
Furniture stores	597
Banking	2,391
Personal services	583
Micellaneous business services	27,759
Auto repair	5,246
Miscellaneous repair	17,198
Amusement services	7,987
Mechanical services	20,053
Miscellaneous unclassified	4,138
Estimated Total	282,653

BIOLOGICAL ACCUMULATION

There is little evidence to judge whether trichloroethylene is accumulating in living systems, and there are conflicting opinions among scientists.

There are some limited data on the occurrence of trichloroethylene in human tissue (Table 5.2). Also, dogs were exposed to relatively high concentrations (7,000 to 20,000 ppm) of trichloroethylene and then, after the animals were sacrificed, tissue from them was analyzed for trichloroethylene (Table 5.3). The limited human data and the lack of exposure and medical histories make these data of little value in judging whether trichloroethylene is accumulating in man. In the case of dogs, such massive doses were given by inhalation that judgments about accumulation in living tissues are impossible.

A Study Panel on Assessing Potential Ocean Pollutants (1975) reports that the bioaccumulation of low-molecular-weight chlorinated hydrocarbons is quite low compared with accumulation of chlorinated pesticides in vertebrates. This same group reports on another study in which it was determined that bioaccumulation factor is determined by the partition of the compound between the water and the tissues of the organism, and further that the log of bioaccumulation is linearly related to the log of the partition coefficient between octanol and water for some compounds. This relationship offers a method of estimating bioaccumulation. A compound such as trichloroethylene would act similarly to carbon tetrachloride in organisms, exhibiting rapid uptake to steady-state concentration and rapid clearance.

By far the most definitive study on bioaccumulation was carried out by Pearson and McConnell (1975). On the basis of results of an extensive analysis of a large number of species (Table 5.4), these authors made some estimates of bioaccumulation in nature. They estimated that the maximum overall increase in concentration, between seawater and the tissues of animals at the top of food chains such as fish liver, bird eggs, and seal blubber, is less than 100-fold for a solvent like trichloroethylene; while a higher molecular weight chlorinated compound such as hexachlorobutadiene would have a maximum increase of 1000-fold. They further concluded that the pattern of extensive bioaccumulation in marine food chains, which is postulated for chlorinated insecticides, does not appear. In laboratory tests where organisms are maintained for up to 3 months in apparatus similar to that used for toxicity determinations, Pearson and McConnell (1975) have shown that bioaccumulation can occur. These results indicate the following: (1) the concentration of chlorinated hydrocarbons accumulated in a tissue tends to an asymptotic level, (2) concentrations in fatty tissues such as liver are higher than in muscle (concentration is proportional to fat content), and (3) when the test organism is returned to clean seawater, the concentration of the chlorinated hydrocarbon in the tissue falls. These researchers conclude that there is no evidence for the bioaccumulation of C_1/C_2 compounds in food chains and the maximum concentrations found in the higher trophic levels are still only parts per 10^8 by mass.

TABLE 5.2. OCCURRENCE OF TRICHLOROETHYLENE IN HUMAN TISSUE

Age of Subject	Sex	Tissue	Concentration, µg/kg (wet tissue)
76	Female	Body fat	32
		Kidney	<1
		Liver	5
		Brain	1
76	Female	Body fat	2
		Kidney	3
		Liver	2
		Brain	<1
82	Female	Body fat	1.4
		Liver	3.2
48	Male	Body fat	6.4
		Liver	3.5
65	Male	Body fat	3.4
		Liver	5.2
75	Male	Body fat	14.1
		Liver	5.8
66	Male	Body fat	4.6
74	Female	Body fat	4.9

Source: McConnell et al., 1975.

TABLE 5.3. TRICHLOROETHYLENE RECOVERED FROM TISSUE

Animal Number	Mode of Exposure	Concentrations, mg %, wet weight						
		Adrenal	Blood	Brain	Fat	Heart	Kidney	Liver
12	Acute	22.4	72.5	17.0	17.9	8.6	1.6	27.0
15	Acute	6.24	46.0	15.1	14.7	5.0	8.2	9.6
16	Acute	--	52.7	19.7	--	5.4	5.8	38.8
17	Acute	--	22.3	--	4.8	4.2	3.6	10.8
20	Acute	22.5	28.4	8.2	70.4	18.9	3.2	9.2
25	Acute X3	13.8	50.0	20.9	70.5	13.9	17.5	49.4
14	Chronic-acute	60.6	46.1	--	--	7.5	21.1	20.6
21	Chronic-acute	23.1	50.6	23.6	22.1	12.9	5.3	9.7
19	Chronic	--	9.6	2.7	30.7	1.2	1.0	3.2
22	Chronic	0.94	0.13	0.22	14.4	0.11	0.13	0.12
24	Chronic	1.06	0.25	0.22	6.5	0.11	0.25	0.25

		Lung	Muscle	Pancreas	Spinal Cord	Cerebro Spinal Fluid	Spleen	Thyroid
12	Acute	2.8	2.7	--	8.8	--	0.71	--
15	Acute	2.2	--	3.2	--	3.8	3.9	2.0
16	Acute	0.92	0.15	9.8	--	1.5	1.2	6.6
17	Acute	0.92	3.3	6.4	--	0.61	5.4	--
20	Acute	0.40	5.1	14.1	--	1.7	1.3	3.9
25	Acute X3	10.4	9.3	43.8	28.3	--	5.1	14.1
14	Chronic-acute	2.0	--	8.1	--	0.15	--	5.8
21	Chronic-acute	1.3	3.8	16.0	--	1.8	8.5	7.4
19	Chronic	0.53	4.1	2.5	--	0.15	0.71	1.1
22	Chronic	0.26	0.45	<0.05	0.13	0.15	<0.05	<0.05
24	Chronic	0.13	0.30	0.28	0.13	0.15	0.12	0.63

Source: U.S. Environmental Protection Agency, 1975a.

TABLE 5.4. CHLORINATED HYDROCARBONS IN MARINE ORGANISMS
(concentrations expressed as parts per 10^9 by mass on wet tissue)

Species	Source	CCl_2CHCl	CCl_2CCl_2	$CH_2CCl_2+CCl_4$	
		Invertebrates			
Plankton	Liverpool Bay	0.05-0.4	0.05-0.5	0.03-10.7	0.04-0.9
Plankton	Torbay	0.0	2.3	2.2	
Nereis diversicolor (ragworm)	Mersey Estuary	ND	2.9	0.6	
Mytilus edulis (mussel)	Liverpool Bay	4-11.9	1.3-6.4	2.4-5.4	
	Firth of Forth	9	9	10	2
	Thames Estuary	8	1	5	0.7
Cerastoderma edule (cockle)	Liverpool Bay	6-11	2-3	0-2	0.4-1
Ostrea edulis (oyster)	Thames Estuary	2	0.5	0.9	0.1
Buccinum undatum (whelk)	Thames Estuary	ND	1	6	0.9
Crepidula fornicata (slipper limpot)	Thames Estuary	9	2	4	0.3
Cancer pagurus (crab)	Tees Bay	2.6	2.3	8.4	
	Liverpool Bay	10-12	8-9	5-34	3-5
	Firth of Forth	15	7	1	2
Carcinus maenas (shore crab)	Firth of Forth	12	6	14	3
Eupagurus bernhardus (hermit crab)	Firth of Forth	15	15	0.7	1
	Thames Estuary	5	2	2	0.2

TABLE 5.4. (Continued)

Species		Source	CCl_2CHCl	CCl_2CCl_2	CH_2CCl_2+CCl_4	
Crangon crangon (shrimp)		Firth of Forth	16	3	2	6
Asterias rubens (starfish)		Thames Estuary	5	1	5	0.8
Solaster sp. (sunstar)		Thames Estuary	2	2	3	0.2
Echinus esculentus (sea urchin)		Thames Estuary	1	1	3	0.1
			Marine algae			
Enteromorpha compressa		Mersey Estuary	19-20	14-14.5	24-27	
Ulva lactuca		Mersey Estuary	23	22	12	
Fucus vesiculosus		Mersey Estuary	17-18	13-20	9.4-10.5	
Fucus serratus		Mersey Estuary	22	15	35	
Fucus spiralis		Mersey Estuary	16	13	17	
			Fish			
Raja clavata (ray)	flesh	Liverpool Bay	0.8-5	0.3-8	2-13	
	liver	Liverpool Bay	5-56	14-41	1.5-18	
Pleuronectes platessa (plaice)	flesh	Liverpool Bay	0.8-8	4-8	0.7-7	
	liver	Liverpool Bay	16-20	11-28	2-47	

TABLE 5.4. (Continued)

Species		Source	CCL_2CHCl	CCl_2CCl_2		CH_2CCl_2+CCl_4
Platycthys flesus	flesh	Liverpool Bay	3	2	4	2
(flounder)	liver	Liverpool Bay	2	1	3	0.3
Limanda limanda	flesh	Liverpool Bay	3-5	1.5-11		1.3-8
(dab)	liver	Liverpool Bay	12-21	15-30		2-14
Scomber scombrus	flesh	Liverpool Bay	5	1	5	2
(mackerel)	liver	Liverpool Bay	8	ND	3	ND
Limanda	flesh	Redear, Yorks	4.6	5.1		9.9
limanda	flesh	Thames Estuary	2	3	4	0.3
Pleuronectes platessa	flesh	Thames Estuary	3	3	3	0.9
Solea solea	flesh	Thames Estuary	2	4	2	6
(sole)	guts	Thames Estuary	11	1	26	1
Aspitrigla	flesh	Thames Estuary	11	1	4	0.6
cuculus	guts	Thames Estuary	6	2	10	0.3
(red gurnard)						
Trachurus trachurus	flesh	Thames Estuary	2	4	1	2
(scad)						
Trisopterus luscus	flesh	Thames Estuary	2	2	2	0.3
(pout)						
Squalus acanthias	flesh	Thames Estuary	3	1	ND	1
(spurdog)						

TABLE 5.4. (Continued)

Species		Source	CCl_2CHCl	CCl_2CCl_2	$CH_2CCl_2+CCl_4$
Scomber scombrus (mackerel)	flesh	Torbay, Devon	2.1	ND	2.4
Clupea sprattus	flesh	Torbay, Devon	3.4	1.0	5.6
Gadus morrhus (cod)	flesh	Torbay, Devon	0.8	<0.1	3.3
	air bladder	Torbay, Devon	<0.1	3.6	NA
Sea and freshwater birds					
Sula bassana (gannot)	liver	Irish Sea	4.5-6	1.5-3.2	1.2-1.9
	eggs	Irish Sea	9-17	4.5-26	17-20
Phalacrocerax aristotelis (shag)	eggs	Irish Sea	2.4	1.4	39.4-41
Alca torda (razorbill)	eggs	Irish Sea	23-26	19-29	35-43
Rissa tridactyla (kittiwake)	eggs	North Sea	33	25	40
Cygnus olor (swan)	liver	Frodsham Marsh	2.1	1.9	4.7
	kidney	(Merseyside)	14	6.4	2.4
Gallinula chloropus (moorhen)	liver	(Merseyside)	6	3.1	1.6
	muscle	(Merseyside)	2.5	0.7	1.1
	eggs	(Merseyside)	6.2-7.8	1.3-2.5	14.5-21.8
Anas platyrhyncos (mallard)	eggs	(Merseyside)	9.8-16	1.9-4.5	4.2-24

TABLE 5.4. (Continued)

Species	Source	CCl_2CHCl	CCl_2CCl_2	$CH_2CCl_2+CCl_4$
		Mammals		
Halichoerus grypus (grey seal)	blubber Farne Is.	2.5-7.2	0.6-19	16-30
	liver Farne Is.	3-6.2	0-3.2	0.3-4.6
Sorex araneus (common shrew)	Frodsham Marsh	2.6-7.8	1	2.3-7

Source: Pearson and McConnell, 1975.

Note: NA = no analysis; ND = not detectable.

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